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AGRICULTURAL MEMORANDUM NO 1050

PROTECTION AGAINST FROST DAMAGE TO POTATOES STORED IN BULK ON A CO DURHAM HILL FARM

During 1982 the Meteorological Office was tasked with investigating the reasons for frost damage to potatoes stored in a recently erected multi purpose storage shed at a farm situated in undulating country a few miles to the East of Bishop Auckland. The shed, at an altitude of 200m, and only 100m from a hill crest, was built into the slope so that 2.5m of the North wall was below local ground level and with the corrugated asbestos roof forming a continuation of the ground shape. (Fig 1)

In order to maintain the buildings flexibility on this mixed farm, insulation of the roof was not an option so attention was concentrated on the details of the protection given to the potato stack within the shed.

For several years the method of protecting potatoes in the present and previously used buildings was to surround the stack with walls of straw bales and cover the domed top of the potatoes with loose straw. When damage by frost was likely, the depth of straw was increased. Any excess heat generated within the stack was convected away by allowing, for short periods, air to enter at the stack base.

Potatoes grown on this farm are a variety suitable for making chips, most of the output going to the local retail trade. As potatoes were regularly removed from the stack and because the storage period rarely extended beyond April, a higher than usual stack temperature was deemed permissible. With this in mind the farmer was advised, for the 1981-2 storage period, to increase, to two bales, the thickness of the protective stack walls where the store wall was cut into the hillside and to four bales on the South side of the stack, (Fig 2) both walls to extend four bales above the top of the stored potatoes which were to be level at a height of 3m. The stack was then covered with two layers of straw bales, the joints of which were overlapped to reduce heat loss and with the joints between the bales in the top layer sealed tightly with loose straw.

At about 3m intervals over the top of the stack single bales were left loose enough to permit temporary removal for ventilation. Between ventilation, however, the joints between the bales were resealed with loose straw.

A bimetallic thermograph, fitted with a weekly clock and chart was housed in a small void on top of the potatoes and under the lower layer of bales and a second thermograph was hung at about stack top height, in a part of the store unaffected by heat escaping from the stack, in order to measure ambient temperature. When charts were changed the temperature of the potatoes in the void was measured using an infra red detector themometer (Ref 1) and the performance of the second thermograph was checked regularly with an Assman psychrometer. This second thermograph was to be used as a guide as to when to open or close the main doors of the store to either remove excess heat, or more importantly, prevent entry of excessively cold air.

Results 1981-82

Temperature records were made from the 27th November, 1981 until the 30th December, 1981, through the start of one of the coldest winter periods this century. Outside air temperatures were average for late November but quickly fell to well below average so that by mid December outside air temperatures of -4°C to -8°C had been reported locally. These levels were again reached during the last week of the month and for the last half of the month ground temperatures, at 30cm depth, were 2½°-3°C below average.

The thermograph records made within the store (Fig 3) show that air temperatures were at or below 0°C for 95% of the time from the 6th of December until the end of the month. Minimum shed temperatures ranged from -2°C to -5°C on most days and reached -7°C during the night of the 10th-11th. The highest December temperature recorded was +2°C for a few hours on the 28th and 29th.

The temperature of the potatoes at the top of the stack (Fig 4) was 9.7°C on the 27th November, rose to only 11°C on the 4th December after which time it fell steadily to 9.2°C by the 29th December.

All measuring equipment was recovered on the 5th January 1982 by which time sales had reduced the stack to the position of the measuring void. By carefully recovering the exposed end of the stack as each batch of potatoes was sold, losses due to frosting amounted to less than 2cwt.

Discussion 1981-82 storage period

The potatoes were in the stack by the time measurements started but it was deduced from local Met data that they had been lifted from ground having a temperature of 8°C and put on to the concrete floor of the shed which was at the same temperature.

In the cold conditions of December the stack was vented only to reduce condensation at the top of the stack. Continued potato growth after stacking raised the stack top temperature to only 11°C, well below the recommended curing level of 14°C. It was unlikely, therefore, that the bottom of the stack reached much above 8°C.

1982-83 Storage period

Measurements were repeated during the first part of the storage period of 1982, namely between 18th November, two days after the stack was built, until the 21st December. The stack was protected by the same arrangement of bales as in the previous year. The inclusion of a perforated narrow bore plastic tube during building of the stack allowed the stack temperature at a height of 0.5m above the concrete floor to be recorded using a remote reading mercury in steel thermograph. (Fig 2)

As a close correlation had been found the previous year between the slowly changing stack top temperature measured by the infra red detector thermometer and recorded by the bimetallic thermograph the latter was dispensed with. This allowed use of the second element of the mercury in steel thermograph, housed in an anti-radiation shield, (Ref 2) to measure the ambient air temperature of the shed.

Results 1982

Outside air and ground temperatures for the first two weeks of the measuring period were average for the time of year. Thereafter, the air frosts which occurred were less severe than those at the same time in the previous year. Below zero temperatures, however, were recorded within the store shed on the 1st, 7th, 12th, 18th, and 19th December, (Fig 5) with minima of -2.5°C, -0.8°C, -1.7°C, -2.1°C and -1.6°C respectively.

Ground temperatures at lifting time, 16th November, were measured at 8°C and the potatoes were put onto concrete which had a measured temperature of 7°C. Within two days the stack top temperature had risen to 11°C, which, by judicious control of the shed doors, was maintained until the 6th December. The last stack top temperature measured was 10.5°C on the 21st December.

Stack base temperature, measured at 50cm above the concrete floor, was 7°C on the 18th November from which level it lowered steadily to 3°C on the 21st December. (Fig 5)

Loss of potatoes due to frosting was again negligible.

General discussion

Most crops of potatoes are placed on to concrete floors which at lifting time are rarely above 8°C. Even at the maximum altitude for potato growing and storage, however, the temperature of floors which are covered by a stored crop is unlikely to fall below 0°C throughout most winters provided the base of the stack is sealed to prevent entry of sub freezing air and, between venting periods, air ducts are resealed thoroughly.

Stack conditions can usually only be assessed by inspection of the stack top after removing any protective covering. If condensation is present or the stack top is deemed to be too hot the only remedy available is to vent the stack by allowing air to enter at the stack base. The present study has shown that even where stringent measures are taken to conserve heat, only the top of the stack warms appreciably and a gradient of temperature remains between stack top and bottom. Indeed, measurements made when the stack top was temporarily dismantled showed that most of the temperature gradient occurred in the top half metre of the stack.

Loose dry straw applied to the top of a stack of potatoes is believed to give some control of condensation. It will not, however, even when applied to a considerable depth retain heat generated by continued growth of the crop within the stack, particularly if straw from broken bales is used. The stems of straw in these are usually broken into short lengths during the harvesting and baling. It was interesting to learn during conversations with one retired local farmer that the 'loose straw' he referred to had had a thicker stem, was in relatively long lengths and was used on a dome topped stack of potatoes to make a rudimentary form of "thatching", so providing a more effective insulation than can be achieved with loosely applied modern straw.

The first venting of stacks built in mid November may not be until well into December by which time, particularly at the higher altitude stores, outside air temperatures will often be below 0°C. As the temperature in the lower half of a stack can steadily fall right from the start of storage, stack base temperatures are likely to be much lower than stack top conditions suggest. Great care must, therefore, be taken to ensure that no sub freezing air is allowed into the stack base even during short periods of venting.

The temperature conditions met with during this study are likely to occur in five years out of ten, particularly at the higher level stores. Even where 'curing' is attempted, it is unlikely that the lower parts of stacks will ever, on such cold floors, reach the recommended curing temperature of 12-14°C. It may be worth

attempting, therefore, to make use of the heat storing capacity of the thick concrete floors of crop stores, many of which are empty for many weeks before stacks are built.

The temperature of most floors will be 14-16°C during August and early September after which time it will fall at about 3-4°C per month. Insulation of such a floor in late August, by covering with thick quilts or two or three layers of tightly wedged straw bales, the joints of which are staggered to reduce heat loss, should ensure that, if the insulation is removed immediately prior to storage time, the potatoes could be put on to a floor with a temperature of about 12°C. With this aid the lower part of the stack will achieve near curing temperatures and the large temperature differences between stack top and bottom, which makes temperature control by venting so difficult, will be reduced. After curing, provided care is taken to vent only when the ambient air is above 0°C and not moist, the lower, now warmer, parts of the stack will not be so prone to damage.

Conclusion

This study has shown that frosting risk can be much reduced in small 'naturally ventilated' stacks, by the provision of adequately thick and draught free side walls to the stack, a substantial and carefully managed top cover and with venting controlled by reference to simple temperature measurements made at the top, bottom and outside of the stack. The floor insulation suggested, though costly in labour terms may well prove to be cost effective in that fewer potatoes may be lost due to frosting.

The co-operation of Mr Sidney Blacket, his family and staff of East Farm, Middlestone, Co Durham is much appreciated as is their kind forbearance during the interruption to their normal work when equipment was installed in the stack and during the writers' ad hoc visits for detailed measurements and servicing of equipment.

February 1985

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Index: Potatoes; Storage; Frost Damage; Co Durham.

Note: Any comments or suggestions relating to this paper should be made direct to the author.

References:- 1. Infra Red detector, 'Instatherm' Model 14-220-1 made by Barnes Engineering Co, Stamford, Connecticut, USA.

2. Meteorological Office pattern Anti-Radiation Shield - Details obtainable from Met O Harrogate.

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FIG. 1.

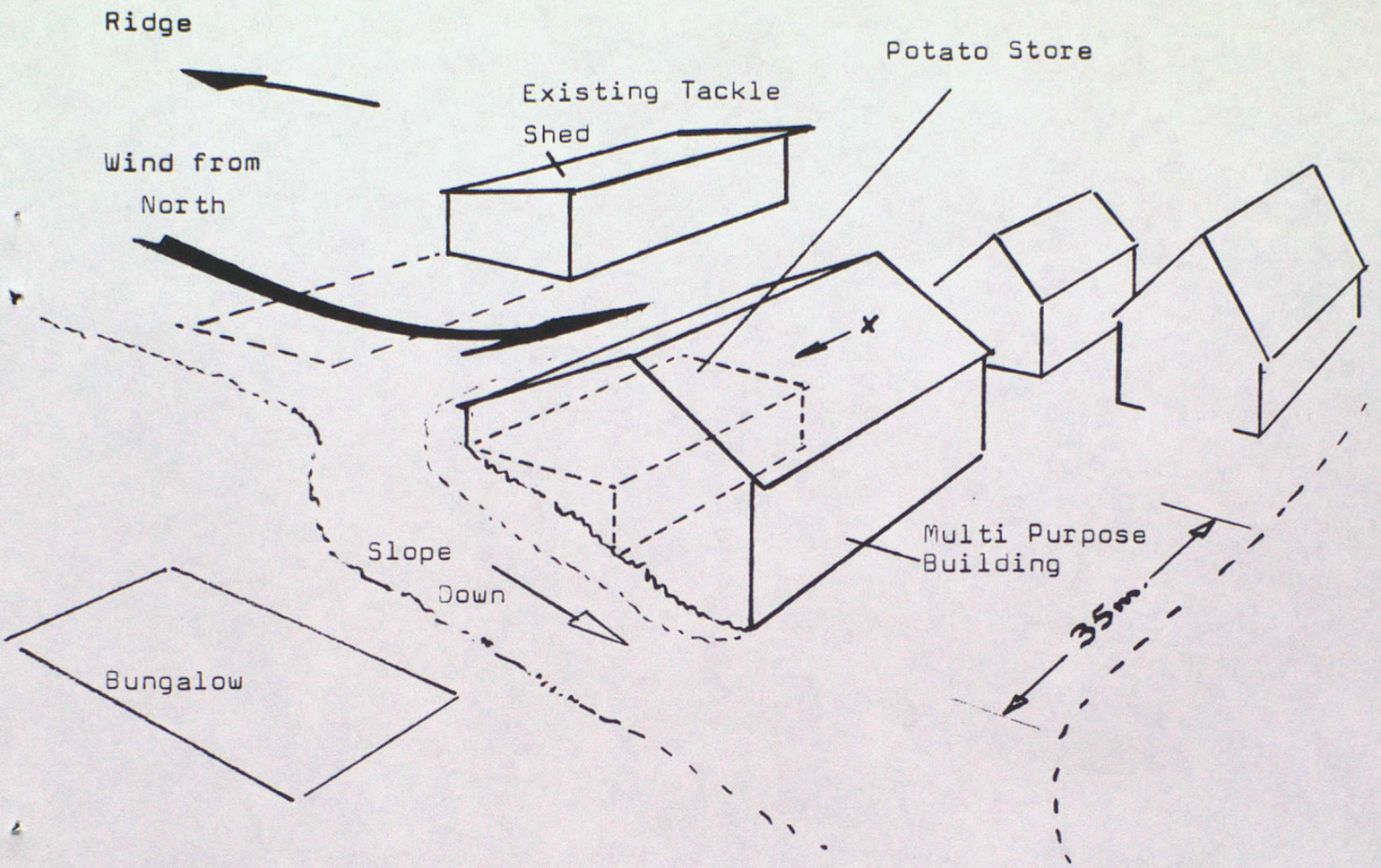

Ridge
Potato Store
Existing Tackle
Shed
Wind from
North
X
Slope
Down
Multi Purpose
Building
35m
Bungalow

FIG. 2.

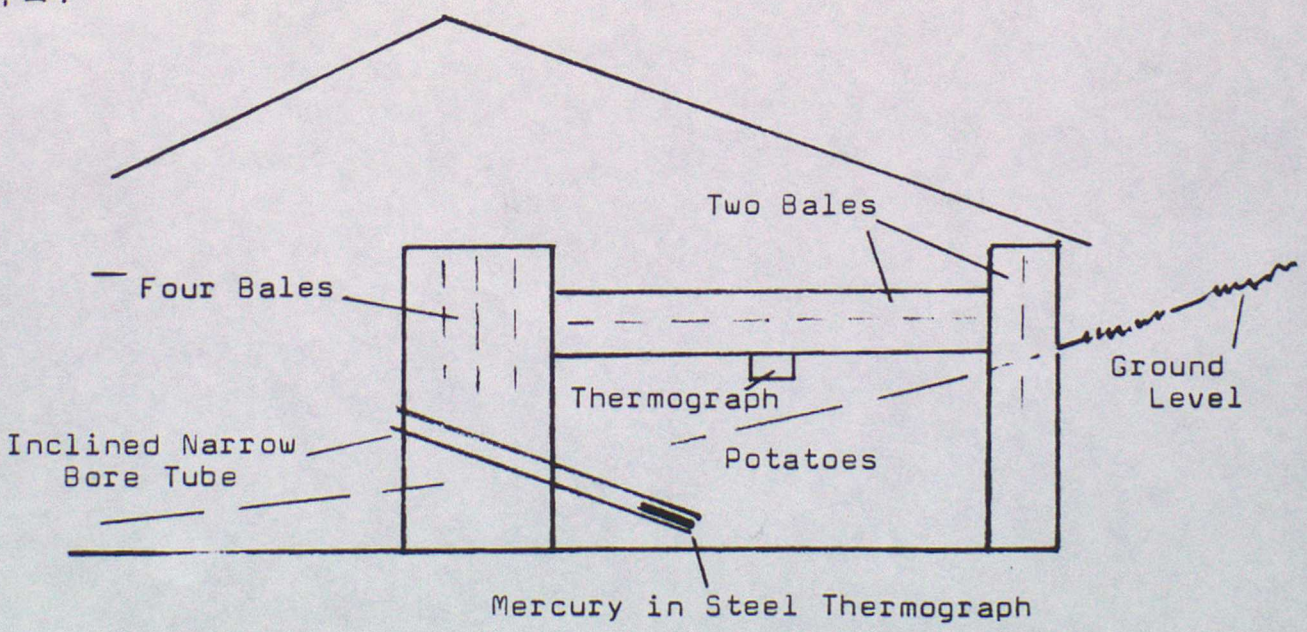

Two Bales
Four Bales
Thermograph
Ground
Level
Inclined Narrow
Bore Tube
Potatoes
Mercury in Steel Thermograph

FIG 3.

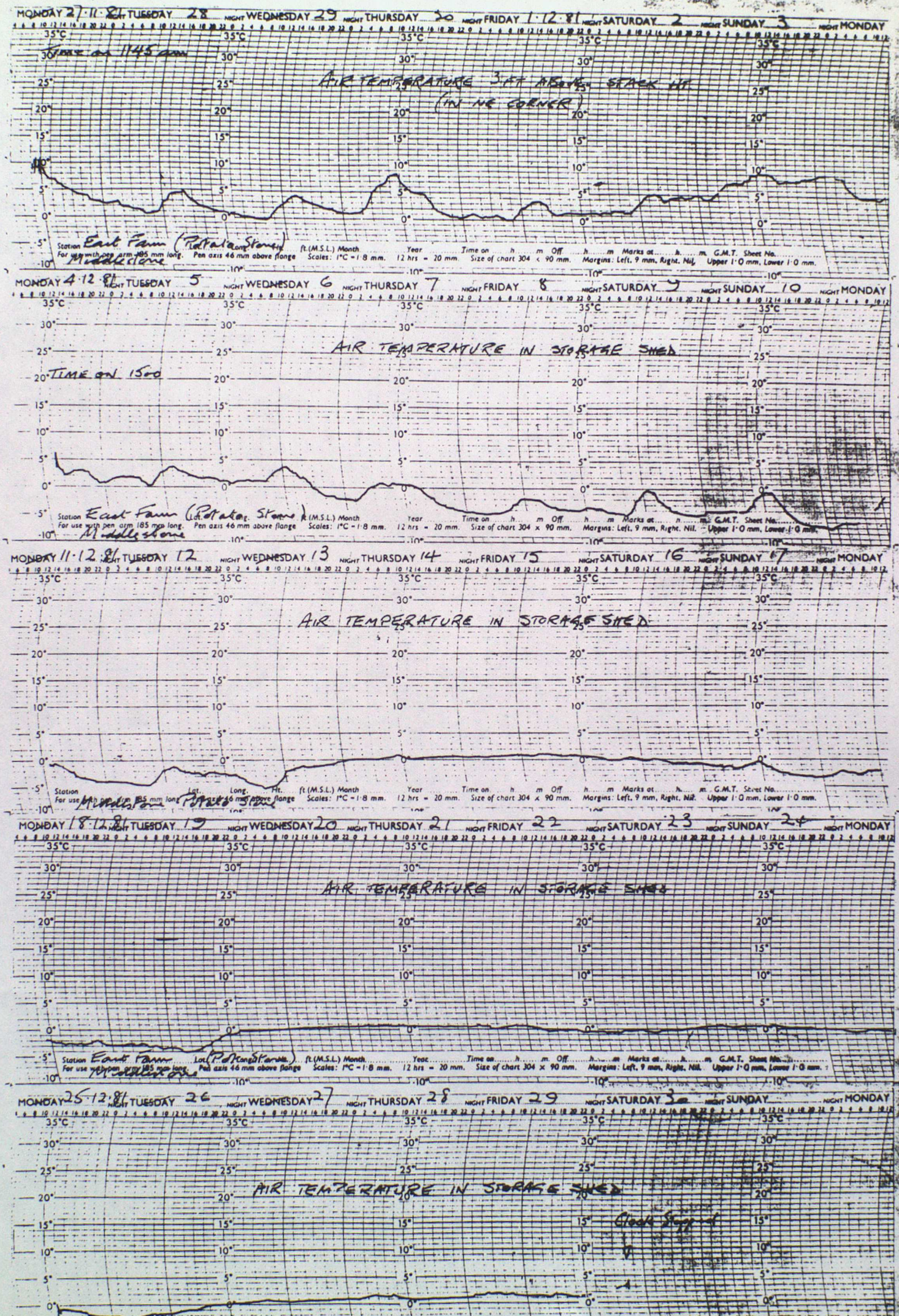

MONDAY 27·11·81 TUESDAY 28 WEDNESDAY 29 THURSDAY 30 FRIDAY 1·12·81 SATURDAY 2 SUNDAY 3 MONDAY
AIR TEMPERATURE 3 FT ABOVE STACK HT (IN NE CORNER)
Time on 1145 am
Station East Farm (Rotating Stone) Middlestone
MONDAY 4·12·81 TUESDAY 5 WEDNESDAY 6 THURSDAY 7 FRIDAY 8 SATURDAY 9 SUNDAY 10 MONDAY
AIR TEMPERATURE IN STORAGE SHED
Time on 1500
Station East Farm (Rotating Stone) Middlestone
MONDAY 11·12·81 TUESDAY 12 WEDNESDAY 13 THURSDAY 14 FRIDAY 15 SATURDAY 16 SUNDAY 17 MONDAY
AIR TEMPERATURE IN STORAGE SHED
Station Middlestone Lat. Long. Ht. (Rotating Stone)
MONDAY 18·12·81 TUESDAY 19 WEDNESDAY 20 THURSDAY 21 FRIDAY 22 SATURDAY 23 SUNDAY 24 MONDAY
AIR TEMPERATURE IN STORAGE SHED
Station East Farm Middlestone (Rotating Stone)
MONDAY 25·12·81 TUESDAY 26 WEDNESDAY 27 THURSDAY 28 FRIDAY 29 SATURDAY 30 SUNDAY MONDAY
AIR TEMPERATURE IN STORAGE SHED
Clock Stopped
For use with pen arm 185 mm long. Pen axis 46 mm above flange Scales: 1°C = 1·8 mm. 12 hrs = 20 mm. Size of chart 304 x 90 mm. Margins: Left. 9 mm, Right. Nil. Upper 1·0 mm, Lower 1·0 mm.

FIG 4.

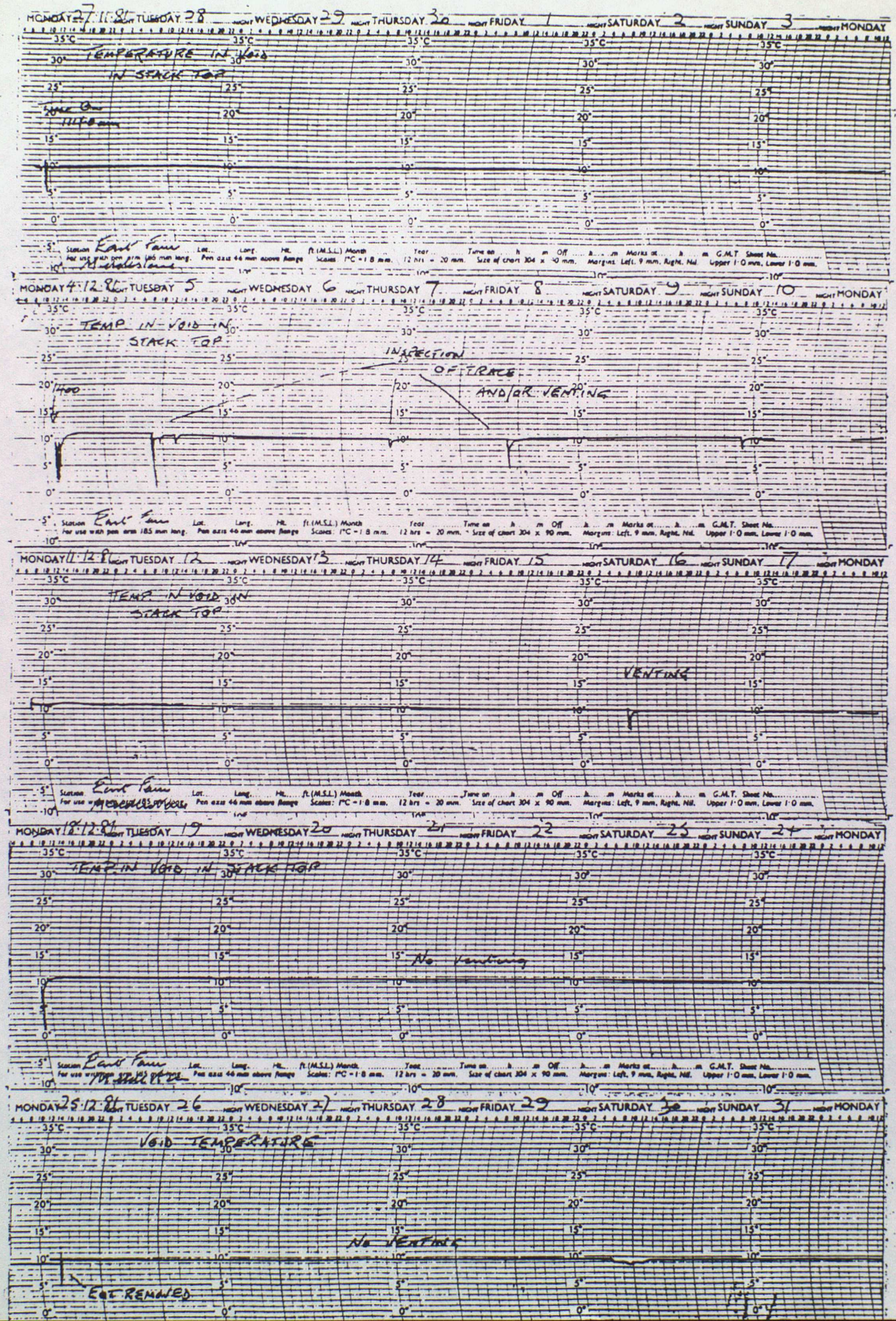
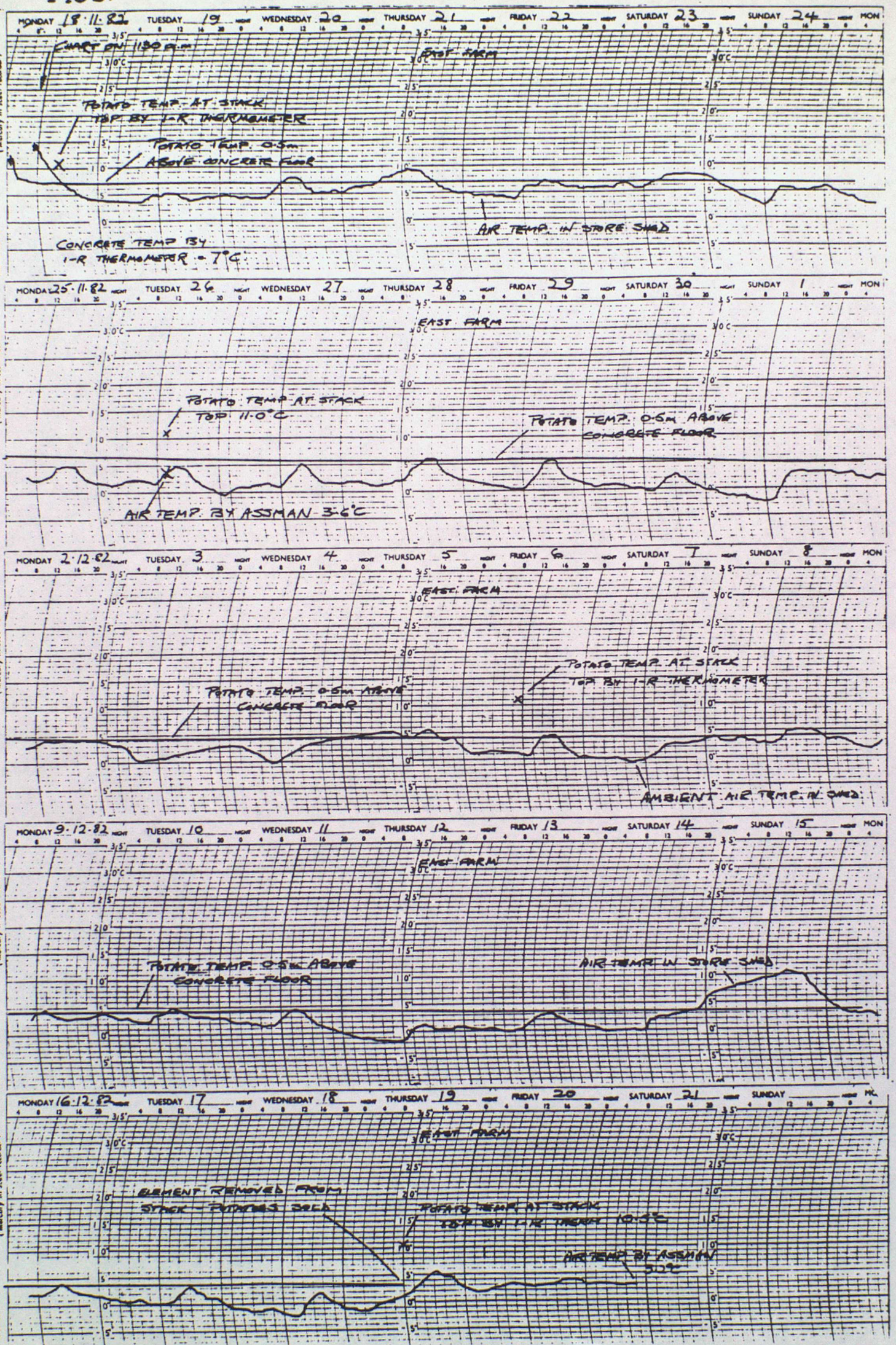

MONDAY 27 12 84 TUESDAY 28 WEDNESDAY 29 THURSDAY 30 FRIDAY 1 SATURDAY 2 SUNDAY 3 MONDAY
TEMPERATURE IN VOID
IN STACK TOP
Size 0m
1148 mm
MONDAY 4 12 84 TUESDAY 5 WEDNESDAY 6 THURSDAY 7 FRIDAY 8 SATURDAY 9 SUNDAY 10 MONDAY
TEMP IN VOID IN
STACK TOP
INSPECTION
OF TRACE
AND/OR VENTING
MONDAY 11 12 84 TUESDAY 12 WEDNESDAY 13 THURSDAY 14 FRIDAY 15 SATURDAY 16 SUNDAY 17 MONDAY
TEMP IN VOID IN
STACK TOP
VENTING
MONDAY 18 12 84 TUESDAY 19 WEDNESDAY 20 THURSDAY 21 FRIDAY 22 SATURDAY 23 SUNDAY 24 MONDAY
TEMP IN VOID IN STACK TOP
No Venting
MONDAY 25 12 84 TUESDAY 26 WEDNESDAY 27 THURSDAY 28 FRIDAY 29 SATURDAY 30 SUNDAY 31 MONDAY
VOID TEMPERATURE
No VENTING
EQT REMOVED

FIG 5.


MONDAY 18·11·82
TUESDAY 19
WEDNESDAY 20
THURSDAY 21
FRIDAY 22
SATURDAY 23
SUNDAY 24
MON
CHART ON 1130 a.m.
EAST FARM
POTATO TEMP. AT STACK TOP BY I-R THERMOMETER
POTATO TEMP. 0·5m ABOVE CONCRETE FLOOR
CONCRETE TEMP BY I-R THERMOMETER = 7°C
AIR TEMP. IN STORE SHED
MONDAY 25·11·82
TUESDAY 26
WEDNESDAY 27
THURSDAY 28
FRIDAY 29
SATURDAY 30
SUNDAY 1
MON
EAST FARM
POTATO TEMP AT STACK TOP 11·0°C
POTATO TEMP. 0·5m ABOVE CONCRETE FLOOR
AIR TEMP. BY ASSMAN 3·6°C
MONDAY 2·12·82
TUESDAY 3
WEDNESDAY 4
THURSDAY 5
FRIDAY 6
SATURDAY 7
SUNDAY 8
MON
EAST FARM
POTATO TEMP. 0·5m ABOVE CONCRETE FLOOR
POTATO TEMP. AT STACK TOP BY I-R THERMOMETER
AMBIENT AIR TEMP. IN SHED
MONDAY 9·12·82
TUESDAY 10
WEDNESDAY 11
THURSDAY 12
FRIDAY 13
SATURDAY 14
SUNDAY 15
MON
EAST FARM
POTATO TEMP. 0·5m ABOVE CONCRETE FLOOR
AIR TEMP IN STORE SHED
MONDAY 16·12·82
TUESDAY 17
WEDNESDAY 18
THURSDAY 19
FRIDAY 20
SATURDAY 21
SUNDAY
MON
EAST FARM
ELEMENT REMOVED FROM STACK - POTATOES COLD
POTATO TEMP AT STACK TOP BY I-R THERM 10·5°C
AIR TEMP BY ASSMAN 5·0°C